Firm Name: *Radiation Monitoring Devices, Inc.*
Contract Number: *NNX11CH32P*
Project Title: *High-resolution detector for at-wavelength metrology of X-ray optics*

A. Identification and Significance of Innovation

Since the launch of the first X-ray focusing telescope in 1963, the development of grazing incidence X-ray optics has been crucial to the development of the field of X-ray astronomy. The recent Decadal Survey also highlights the important contribution that X-ray astronomy can make in addressing some of the most pressing scientific questions about black holes, cosmology and the ebb and flow of energy and matter in the evolving universe, and recognizes the research needed to mature the key enabling technology of X-ray optics. The proposed development directly addresses this need by providing a unique detector designed specifically to support the development of the next generation of X-ray telescopes, which will allow researchers and engineers to characterize such X-ray telescopes with high accuracy, and thereby optimize their performance and best utilize their gathered data. By the end of the Phase II program we will have developed a fully calibrated detector ready for use at various facilities, including NASA's Marshall Space Flight Center (MSFC) and other NASA-funded research centers such as the Harvard-Smithsonian Center for Astrophysics and Columbia University.

B. Technical Objectives and Work Plan

The goal of this research project is to develop a high spatial resolution detector for at-wavelength metrology of X-ray optics using a special electron multiplying CCD (EMCCD). In addition to its superior spatial resolution, the detector will provide spectral information over a wide energy range of 8 keV to 100 keV, permit X-ray photon counting with rates exceeding tens of KHz, have a large active imaging area, and offer ease of use. The research work was undertaken in collaboration with Lawrence Livermore National Laboratory (LLNL) physicists who are members of X-ray optics team for the Nuclear Spectroscopic Telescope Array (*NuSTAR)* mission.

The Phase I research was divided into three main areas:

1) Optimize the scintillator to be used in the detector in order to maximize the scintillation light reaching the EMCCD, while minimizing resolution losses, to simultaneously achieve high sensitivity and high spatial resolution,

2) Develop algorithms for improved spatial and energy resolution, and

3) Integrate new components and software with our existing EMCCD camera and perform feasibility tests at the Rainwater Memorial Calibration Facility for testing NuSTAR mission optics.

Use results of these studies to finalize design of the detector that will be built in Phase II.

C. Technical Accomplishments

The Phase I research not only succeeded in demonstrating the feasibility of developing a detector suitable for at-wavelength metrology of X-ray optics, but also exceeded expectations by significant margin through actual calibration of a NASA mission optics.

Each of the tasks identified in the proposal was successfully completed during the Phase I.

1) In order to optimize the scintillator four different methods were utilized: such as direct deposition of CsI:Tl scintillator on tapered fiberoptic; exploring different types of reflectors to enhance the amount of scintillation light reaching the EMCCD; controlling the morphology of the CsI:Tl films in order to enhance transparency for minimized self-absorption; and deposition of novel bright scintillators.
2) Algorithms to operate the detector in photon counting mode were developed.
3) A prototype detector was assembled, which played a decisive role in the ground calibration of the two X-ray telescopes that will fly on the NuSTAR mission.

Thus, the Phase I research has laid a firm foundation for the Phase II by establishing the detector feasibility, and for commercializing this detector in Phase III.

D. NASA Applications

The value of this type of detector, a high performance X-ray imaging camera, is evident from our Phase I results where our prototype detector played a crucial role in the ground calibration of the two X-ray telescopes that will fly on the *NuSTAR* mission. This detector, with its enhanced performance, will allow its use for several specific new missions and mission areas, including the future X-ray missions for space astronomical observatories, FOXSI, SRG/ART-XC, and the WHIMex Mission, and for in-situ characterization during X-ray mirror assembly.

E. Non-NASA Commercial Applications

Due to its high intrinsic spatial resolution, individual X-ray and gamma-ray photon counting ability, spectral resolution suitable for many applications, and large imaging area, the proposed detector is expected to find numerous applications in fields of high resolution X-ray/gamma-ray detection, small animal single photon emission computed tomography (SPECT) and other nuclear medicine applications, X-ray medical imaging (including mammography, digital tomosynthesis and computed tomography), time-resolved X-ray diffraction studies at synchrotron sources, dynamic X-ray imaging of hypervelocity projectiles, X-ray microscopy, and low-light optical tomography. With its very high spatial resolution and high frame rate performance, this imaging detector may also be used for dynamic nondestructive evaluations (NDEs) of spacecraft and other components, which are routinely performed for quality assurance and design improvement purposes. The current annual commercial market for X-ray and nuclear imagers is estimated to be several billion dollars, a significant fraction of which represents areas where the proposed detector technology may be utilized.

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